Introduction to Basic Stargazing Part III
By Michael Usher

Before you read this, you need to spend some time out under the stars learning your way around the sky. Now, when you read what I have to say next it will make much better sense. Otherwise you just might say "What is he talking about?" rather than "Oh yeah, I was wondering about that, now I know." Nevertheless, there is still a great deal of information compressed into a few pages, so don't feel bad if you have trouble understanding it. Humans took at least 5,000 years to figure all of this out, it's ok for you to take your time.

You can't spend very much time out under the stars without noticing that *everything* is moving. Most of the motion is obviously because the earth is rotating. (This was not clear to our ancestors, but that is another subject.) The earth rotates 15 degrees an hour and thus that is the speed the stars move. Notice that the actual velocity the stars move is slower near the pole rather than the celestial equator. The 360 degree circle they need to traverse each day is smaller near the pole than the equator, thus they don't need to move as quickly.

The star gazer can't help but notice the slow turning of the sky after 15 minutes or so, but there is another additional motion which is which is superimposed on the daily rotational one. If you go out at the same time each night the stars in the east are ever so slightly higher than they were the night before. You might not notice it the second night, but in a month the sky has rotated an additional 30 degrees over and above the daily rotation. Or to put it another way, the sky at 8:00PM on April 15 looks the same as the sky did at 10:00PM on March 15.

This extra motion is caused by the Earth's annual revolution around the Sun. Any given star rises 4 minutes earlier, (well 3m 56s), than the day before. Over the course of a year that adds up to 24 hours and we are right back exactly where we started. This is why your planisphere has date marks around the circumference.

Every hobby or science has its own technical jargon and this one is no exception. It's time to learn a few words.

The spot in the sky that is directly over your head is known as the **zenith**. Because the Earth is a sphere, no one else in the world shares your zenith exactly – it's yours alone! The spot under your feet is known as the **nadir**. Now draw an imaginary line from the North Celestial Pole, (Polaris is close enough for our purposes), through the zenith and on southwards to the South Celestial Pole. This line is known as the **meridian**. The meridian is a line of some importance; since it is easy to tell with simple instruments when a star crosses it. When a star crosses the meridian, it has reached its highest point above the horizon; the star then begins to descend. The moment the star crosses the meridian is known as its **cumulation**. Our Sun cumulates each day as well, but we give that event a special name due to its importance – we call it noon.

Because noon is easy to determine, towns and villages used to set their clocks by the Sun creating a nightmare of different times across the Earth as each one had a slightly different meridian than every other one. This was eventually smoothed out by the development of time zones, but this still left 24 different times to contend with worldwide. Astronomers needed a standard time of reference to refer to; it was agreed that the **Prime Meridian** would be 0 degrees longitude (it runs thru Greenwich, London). Greenwich Mean Time is the standard reference time of the entire world for astronomers, or it as it is more commonly called **Universal Coordinated Time (UTC)**. (The abbreviation looks a little odd as it is derived from French, not English).

Event times are all given in UTC. Now, when an asteroid is scheduled to smack into the Moon at 3:00AM UTC everyone knows to subtract 5 hours if they live in the EST zone and go outside at 10:00PM if they wish to see it happen.

Planets and other Solar System objects rise and set and cumulate just like the stars do, but they have their own special movements as well and special jargon was developed to describe them all.

All planets revolve around the Sun from *west to east*; to put it another way, if you were floating a few million miles above the Sun's north pole all planets would be seen revolving counter-clockwise. Not just planets, but asteroids as well. Satellites orbiting planets revolve around their primaries counter-clockwise also. For that matter, planets generally rotate counter-clockwise too.
This common motion is termed **direct** or less commonly, **prograde**. Motion running the other way, east to west, is termed **retrograde**. The most amazing thing about retrograde motion is how rare it really is; about the only thing visible to the naked eye that routinely moves in a true retrograde fashion are some (not all) comets.

As the planets travel endlessly about the sun certain positions, called **aspects**, happen frequently from the viewpoint of Earth. An **inferior planet** (orbit inside Earth) will have two greatest **elongations** - an eastern (evening) and a western (morning). At the time of greatest elongation an inferior planet will achieve its largest angular distance from the Sun and will be best placed for viewing. At **inferior conjunction** an inferior planet will be between the Earth and Sun and be invisible unless it is exactly between us, then a rare **transit** will occur. At **superior conjunction** the Sun will be between Earth and the planet and the planet will be invisible. See Diagram 1.

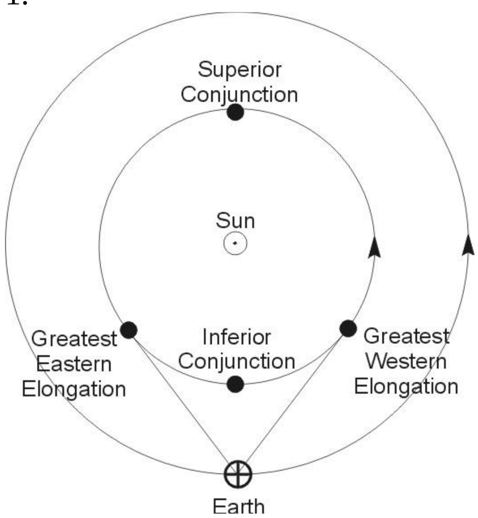


Diagram 1: Aspects of Inferior Planets

A **superior planet** (orbit outside of Earth) will come to **opposition** when it lies directly opposite the Sun in Earth's sky. Earth will then be at its closest point to the superior planet and the planet will be visible all night long. At **conjunction** the superior planet lies behind the Sun and is invisible. Planets can go into conjunction with each other also; at such time, they lay along a very similar line of sight and it can be quite beautiful. A superior planet can also come to **quadrature**; this happens when the Sun and planet lie at a 90-degree angle to one another. At quadrature Mars is distinctly gibbous and Saturn will throw a pronounced shadow on its rings. See Diagram 2 on the next page.

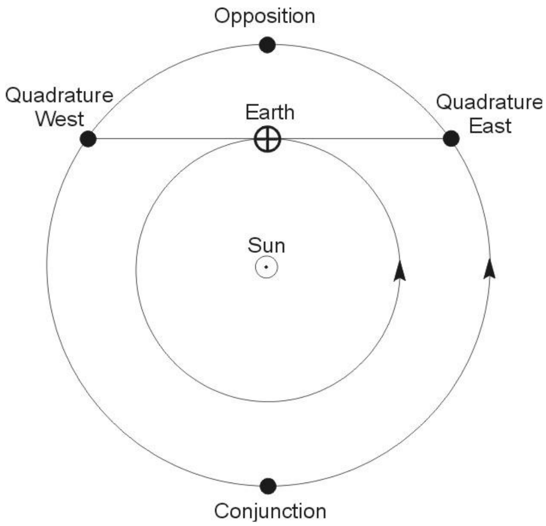


Diagram 2: Aspects of Superior Planets

As all the planets have elliptical orbits and are tilted as well, oppositions and elongations can vary tremendously in quality.
Diagrams are based on illustrations in *Norton's Star Atlas, 19th edition.*

Now a peculiar thing happens when a planet nears opposition. The planet will appear to move in a retrograde fashion. This is not a true retrograde movement, as the planet, as seen from the Sun, always moves in its direct, counterclockwise fashion. The apparent retrograde movement only occurs from an Earth perspective. This confused the heck out of our ancient ancestors and took at least 5,000 years to figure out the reason; their basic assumption that the Earth was immobile was wrong.

Consider our Solar System a racetrack with fixed lanes; each planet occupies a single track and furthermore each planet goes slower the further away it gets from the center. Being on an inside track the Earth moves both faster than, say Mars, *and* has the shorter path. The pit crew sees Earth pass Mars and leave it behind, clearly no planet is changing direction. Earth however, as it comes around the curve to "lap" Mars, sees it slow down and drift backwards. As Earth goes around the next curve Mars appears to begin moving forwards again.

Just to make things more confusing, Mars' orbit is tilted slightly with respect to the Earth's, so Mars traces out a crazy flattened loop in the sky.

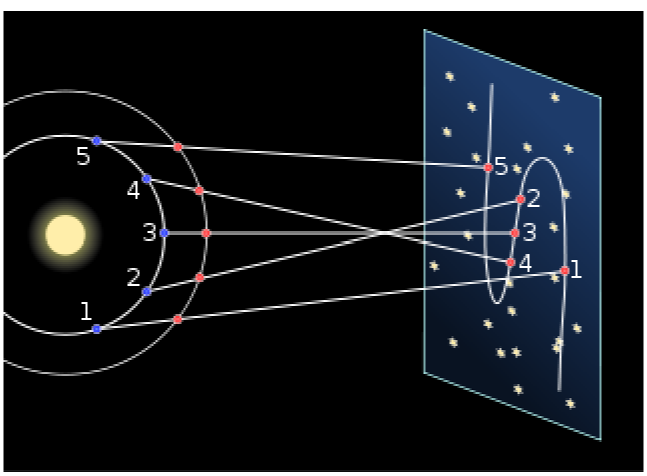


Diagram 3: As Earth (blue) passes a superior planet, such as Mars (red), the superior planet will temporarily appear to reverse its motion across the sky

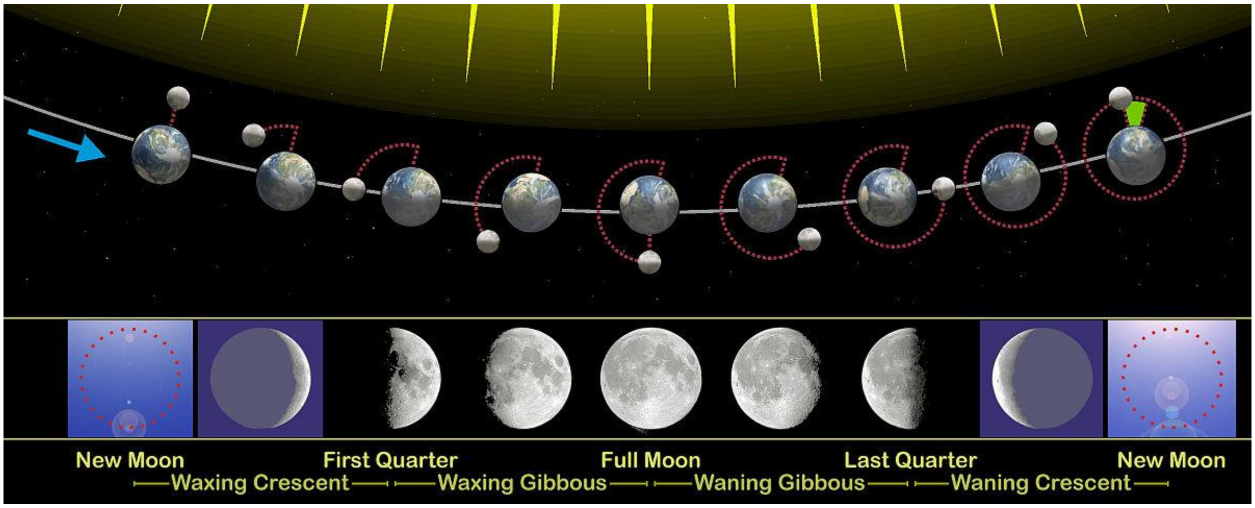
The time it takes Earth to gain a "lap" on Mars is 780 days. This is called Mars' **synodic** period. The synodic period may be defined as the time it takes three Solar System bodies to return to the same arbitrary relative position. (Typically, Earth, Sun and a planet). Opposition is the commonly chosen point for an outer planet, one of the greatest elongations for an inner planet. (Although technically, any point you please can be chosen.). Every Solar System body has a synodic period; the precise length of the period can be slightly variable. Saturn's is 54 weeks; the Moon's is 29.5 days. By no coincidence at all, that is the time from one full Moon to the next.

A planets **orbital period** is the time it takes to go around the Sun with *respect to the stars*. (Also known as the **sidereal period**.) Each Solar System body has its own characteristic orbital period; Jupiter's is 11.86 years.

A **Solar Day** for any planet is the time it takes for the Sun to go from one noon to the next. On Earth that is, by definition, exactly 24 hours. - (an over-simplification, but we will go with it for now). There is also a **Stellar Day**, the time the planet to rotate with respect to the fixed stars. For Earth that happens to be 23 hours, 56 minutes. This 4-minute time differential is the same one discussed at the beginning of this article.

Notice we really haven't talked much about the Moon, there is a reason for that; Isaac Newton once said that working out the motion of the Moon was the only problem that made his head ache! There is no point to dive deeply into the nitty gritty details, but the Moon is one weird satellite by any definition.

Nevertheless there are patterns in the Moon's movement any stargazer can understand. Most noticeable, as everyone knows since early childhood, the Moon has phases. Exactly 50% of the Moon is illuminated at all times. The illuminated portion that we see depends on the Moon's position in its orbit. When at opposition the Moon is full, at conjunction the Moon is new and invisible (usually). At quadrature the Moon is at first or last quarter. (See diagram below).



Phases of the Moon, as seen looking southward from the northern hemisphere. The southern hemisphere will see each phase rotated through 180°. The upper part of the diagram is not to scale, as the Moon is much farther from the Earth than shown here. By Orion 8 - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=11219265

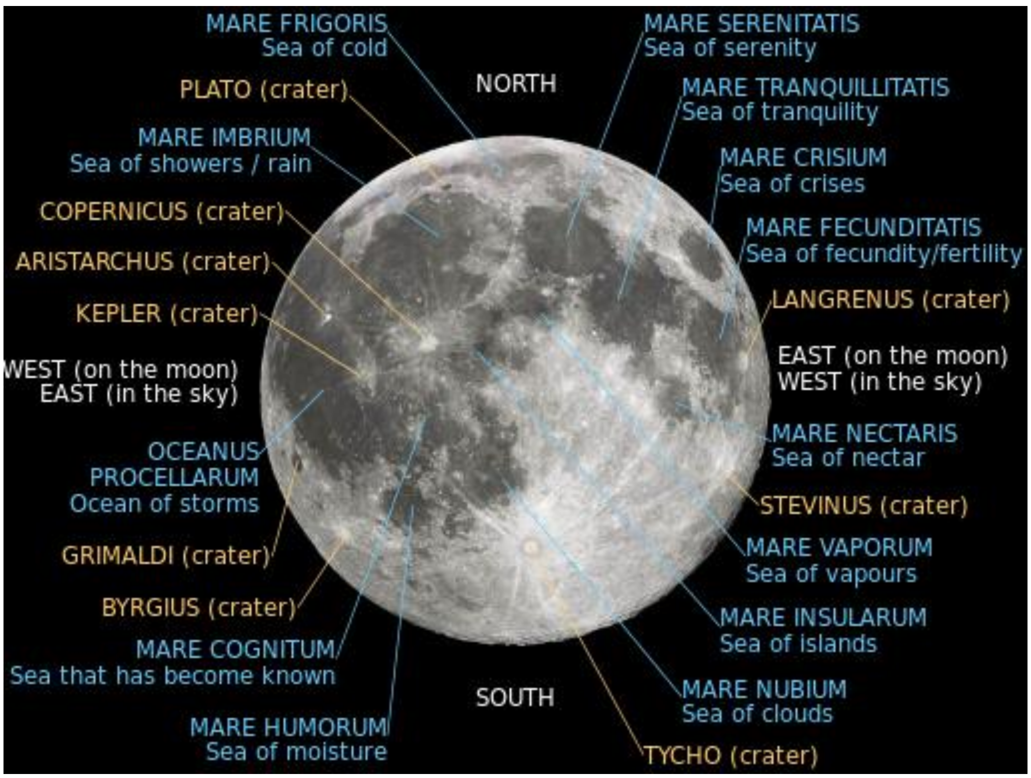
The Moon's orbital period is 27.3 days (with respect to the stars), however time elapsed time between one new Moon and the next is 29.5 days – the synodic period. This is caused by Earth's motion around the Sun; the Moon needs the extra 2.2 days to catch up to the apparent movement of the Sun. The diagram above represents this by the green area on the right.

All satellites in the Solar System go through phases, and most of them always keep the same face to their **primary** – and the Moon is no exception. Called **synchronous rotation**, this is caused by tidal forces, which tend to have a breaking effect on rotation over very long periods of time. While the Earth has succeeded in slowing the Moon's rotation to once an orbit, the Moon has not yet returned the favor as it is not nearly as massive as the Earth. Still the Moon does have a slowing effect on the Earth's rotation that is measurable, but extremely small.

There are a few misconceptions about the Moon. There is no permanent "dark side"; all areas of the Moon receive equal illumination from the Sun except for a few shadowed craters near the poles. The full Moon has no effect on human behaviors like homicides, suicides, traffic accidents or admission to hospitals – dozens of studies have proved this. Nor is there any connection women's menstrual cycles.

The Moon seems huge when near the horizon, and much smaller when high in the sky. This is a pure optical illusion as has been proved innumerable times. Just exactly why it occurs has been the subject of much research; current thinking is that it has to do with the way the brain processes viewing distant objects. Constellations also appear larger than normal when near the horizon.

The Moon is close enough that it can be studied in some detail with binoculars. Contrary to your first impulse the full Moon is not the best time to look. Shadows are missing and the Moon looks flat and uninteresting. Instead choose some other phase – first or last quarter would be a good choice. By tradition, place names on the Moon are given in Latin. See diagram below.



By Peter FreimanCmgleeBackground photograph by Gregory H. Revera - Remake of File:FullMoon2010.jpgBitmap from File:FullMoon2010.jpgOwn work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=14580532

The progress of the Moon's orbit viewed from the surface of the Earth is known as an **apparition**. (Planets have apparitions too.) As with most Solar System objects the Moon moves from West to East. An apparition of the Moon begins as a crescent low in the west. The horns of the crescent invariably point away from the Sun. Each evening thereafter the crescent grows fatter (**waxing**) and the Moon sets roughly 50 minutes later. In about a week the Moon is at first quarter and sets near midnight. After another week, the Moon is at full phase and rises just as the Sun sets and is visible all night long. The Moon then begins to **wane** and after another week is at last quarter and does not rise until midnight. A few more days and the Moon is back to a crescent and rises in the morning just before the Sun does. It then vanishes in the glare of the Sun (a new Moon) until it reemerges in the evening once again to begin another apparition.

The Moon of course is something of a pain to Stargazers, in its glare many stars disappear. As partial compensation, besides eclipses, the Moon provides **occultations**. The Moon covers up many stars temporarily in its motion thru the heavens. For up to an hour the star may be hidden from view. Sometimes the Moon may cover up a bright star such as Aldebaran or Antares; any planet can be occulted also. Times, dates and locations may be discovered on the internet. Occultations can be interesting to view; the star winks out (almost) instantly, a planet takes a moment or two longer.

Useful Tables

If you are going to participate in Astronomy as a hobby, sooner or later you are going to have to learn the Greek Alphabet – at least the lower-case letters. The 400-year-old Bayer Catalog assigns lower-case Greek letters to the brighter stars in each constellation combined with the constellation name. *i.e.* Alpha Centauri or α Centauri (α Cen) as it is printed on charts. You are probably not totally unfamiliar with the characters of the alphabet as they are used quite a bit in High School and College math and science classes. (And they are wildly popular in college fraternities!)

α	alpha	ι	iota	ρ	rho
β	beta	κ	kappa	σ	sigma
γ	gamma	λ	lambda	τ	tau
δ	delta	μ	mu	υ	upsilon
ε	epsilon	ν	nu	φ	phi
ζ	zeta	ξ	xi	χ	chi
η	eta	ο	omicron	ψ	psi
θ	theta	π	pi	ω	omega

There are 88 constellations that cover the sky from pole to pole. Some are traditional, handed down from ancient times, others are more modern – typically 17^{th} or 18^{th} century when the sky was being completely mapped. Constellations from modern times are not bright – they tend to be faint space fillers. By long tradition all constellation names are Latin, and thus when you are speaking about something belonging to a constellation the name takes genitive case. A pain for English speakers, but you get used to it eventually.

Constellation	**Abbr**	**Genitive**	**Meaning**	**Constellation**	**Abbr**	**Genitive**	**Meaning**
Andromeda	And	Andromedae	chained princess	Centaurus	Cen	Centauri	centaur
Antlia	Ant	Antliae	air pump	Cepheus	Cep	Cephei	mythological king
Apus	Aps	Apodis	bird of paradise	Cetus	Cet	Ceti	sea monster
Aquarius	Aqr	Aquarii	water bearer	Chamaeleon	Cha	Chamaeleontis	chameleon
Aquila	Aql	Aquilae	eagle	Circinus	Cir	Circini	compass
Ara	Ara	Arae	alter	Columba	Col	Columbae	dove
Aries	Ari	Arie	ram	Coma Berenices	Com	Comae Berenices	Berenice’s hair
Boötes	Boo	Boötis	herdsman	Corona Australis	CrA	Coronae Australis	southern crown
Caelum	Cae	Caeli	chisel	Corona Borealis	CrB	Coronae Borealis	northern crown
Camelopardalis	Cam	Camelopardalis	giraffe	Corvus	Crv	Corvi	crow
Cancer	Cnc	Cancri	crab	Crater	Crt	Crateris	cup
Canes Venatici	CVn	Canum Venaticorum	hunting dogs	Crux	Cru	Crucis	southern cross

Constellation	Abbr	Genitive	Meaning	Constellation	Abbr	Genitive	Meaning
Canis Major	CMa	Canis Majoris	big dog	Cygnus	Cyg	Cygni	swan
Canis Minor	CMi	Canis Minoris	little dog	Delphinus	Del	Delphini	dolphin
Capricornus	Cap	Capricorni	Sea goat	Dorado	Dor	Doradus	dolphinfish
Carina	Car	Carinae	keel	Draco	Dra	Draconis	dragon
Cassiopeia	Cas	Cassiopeiae	mythological queen	Equuleus	Equ	Equulei	pony
Eridanus	Eri	Eridani	river	Perseus	Per	Persei	Mythological character
Fornax	For	Fornacis	furnace	Phoenix	Phe	Phoenicis	phoenix
Gemini	Gem	Geminorum	twins	Pictor	Pic	Pictoris	easel
Grus	Gru	Gruis	crane	Pisces	Psc	Piscium	fish
Hercules	Her	Herculis	mythological character	Piscis Austrinus	PsA	Piscis Austrini	southern fish
Horologium	Hor	Horilogii	clock	Puppis	Pup	Puppis	poop deck
Hydra	Hya	Hydrae	mythological creature	Pyxis	Pyx	Pyxidis	mariner's compass
Indus	Ind	Indi	Indian (unspecified type)	Reticulum	Ret	Reticuli	eyepiece reticule
Lacerta	Lac	Lacertae	lizard	Sagitta	Sge	Sagittae	arrow
Leo	Leo	Leonis	lion	Sagittarius	Sgr	Sagittarii	archer
Leo Minor	LMi	Leonis Minoris	lesser lion	Scorpius	Sco	Scorpii	scorpion
Lepus	Lep	Leporis	hare	Sculptor	Scl	Sculptoris	sculptor
Libra	Lib	Librae	balance	Scutum	Sct	Scuti	shield
Lupus	Lup	Lupi	wolf	Serpens	Ser	Serpentis	snake
Lynx	Lyn	Lyncis	lynx	Sextans	Sex	Sextantis	sextant
Lyra	Lyr	Lyrae	lyre/harp	Taurus	Tau	Tauri	bull
Mensa	Men	Mensae	Table Mountain	Telescopium	Tel	Telescopii	telescope
Microscopium	Mic	Microscopii	microscope	Triangulum	Tri	Trianguli	triangle
Monoceros	Mon	Monocerotis	unicorn	Triangulum Australe	TrA	Trianguli Australis	southern triangle
Musca	Mus	Muscae	fly	Tucana	Tuc	Tucanae	toucan
Norma	Nor	Normae	carpenter's level	Ursa Major	UMa	Ursae Majoris	great bear
Octans	Oct	Octantis	octant	Ursa Minor	UMi	Ursae Minoris	little bear
Ophiuchus	Oph	Ophiuchi	serpent bearer	Vela	Vel	Velorum	sails
Orion	Ori	Orionis	mythological character	Virgo	Vir	Virginis	maiden
Pavo	Pav	Pavonis	peacock	Volans	Vol	Volantis	flying fish
Pegasus	Peg	Pegasi	mythological winged horse	Vulpecula	Vul	Vulpeculae	fox

There are only a couple of hundred stars that have proper names, and of these there are only about twenty in common use. Generally, all the rest are referred to by their Bayer designation or some other catalog number. You should make an effort learn the locations of the stars listed below. The stars in bold letters are not visible from temperate northern latitudes, *i.e.* New England, but are visible from near tropical latitudes, *i.e.* Florida, and of course the entire southern hemisphere.

Proper Name	**Bayer Designation**	**Magnitude**	**Distance (light years)**
Sirius	α CMa	-1.46	8.6
Canopus	**α Car**	**-.74**	**310**
Rigil Kentaurus	**α Cen**	**-.27**	**4.4**
Arcturus	α Boo	-.05	37
Vega	α Lyr	0.03	25
Capella	α Aur	0.08	42
Rigel	β Ori	0.13	860
Procyon	α CMi	0.34	11
Achernar	**α Eri**	**0.46**	**140**
Betelgeuse	α Ori	0.5	640
Altair	α Aql	0.76	17
Acrux	**α Cru**	**.76**	**320**
Aldebaran	α Tau	0.86	65
Antares	α Sco	0.96	600
Spica	α Vir	0.97	260
Pollux	β Gem	1.14	34
Fomalhaut	α PsA	1.16	25
Deneb	α Cyg	1.25	2,600
Regulus	α Leo	1.39	77
Castor	α Gem	1.62	52
Polaris	α UMi	1.98	430

Planets have abbreviations – a sort of shorthand symbol. Occasionally they will pop up on computer-generated star charts, diagrams and old books. Otherwise these symbols are not much used.

Planet	**Symbol**
Mercury	☿
Venus	♀
Earth	⊕
Mars	♂
Jupiter	♃
Saturn	♄
Uranus	⛢
Neptune	♆
Sun	☉